

### Remarks

This Preliminary Amendment cancels without prejudice original PCT claims 1-19 in the underlying PCT Application No. PCT/DE03/00051, and adds new claims 20-38. The new claims conform to U.S. Patent and Trademark Office rules and do not add new matter to the application.

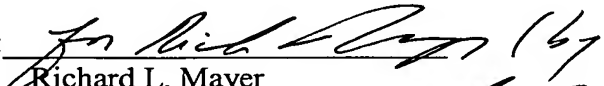
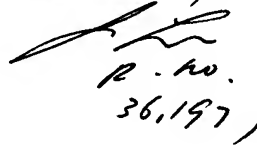
In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(ii) and § 1.125(c), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE03/00051 includes an International Search Report, dated May 16, 2003. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment. Also enclosed is an English translation of the International Preliminary Examination Report dated October 7, 2003.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,  
KENYON & KENYON

Dated: 9/27/04

By:  (67)  
Richard L. Mayer  
(Reg. No. 22,490)  
  
One Broadway  
New York, NY 10004  
(212) 425-7200  
CUSTOMER NO. 26646

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DEVICE, IN PARTICULAR FOR BISTATIC RADAR APPLICATIONS

# FIELD OF THE INVENTION

The present invention is directed to a device for bistatic radar applications, ~~in particular.~~

## 5 BACKGROUND INFORMATION

The fundamental ~~method of functioning~~ operation of pulsed radars for measuring the distance and velocity of objects ~~that is valid to this day,~~ had already been described in 1938 by Col. William Blair of the U.S. Signal Corps. When a microwave carrier undergoes pulse modulation, a signal of a defined pulse duration  $T_p$  is periodically transmitted at the pulse repetition frequency PRF. The signal reflected off of an object is attenuated in the receiver to the baseband range. By analyzing the baseband signal, the signal propagation time  $T$  and possibly the signal Doppler shift  $f_d$  are determined. From the propagation time  $T$ , the object-sensor slant distance  $R$  is derived, ultimately based on the speed of light  $c$ , from the relationship  $R = c \cdot T/2$ , and the object velocity  $v$  is determined, with the carrier frequency being  $f_c$  from the relationship  $v = c/2 \cdot f_d/f_c$ .

~~Customary~~ Conventional pulsed radar systems use the following operating modes:

LPRF (low pulse repetition frequency):

In this case, pulsed radars have such a low pulse repetition frequency PRF, that a unique measurement up to the greatest desired object distance is always possible. However, if velocities occur that can result in  $f_D$  being greater than PRF/2, the velocity determination is no longer unique, however.

HPRF (high pulse repetition frequency):

Here, operation takes place at such a high pulse repetition frequency that the velocity determination in the entire relative velocity range is always unique. The distance measurement is only unique when all objects in the detecting range exclusively have smaller distances than  $c/(2 \text{ PRF})$  to the sensors.

PRF staggering (staggered PRF):

To avoid so-called blind speeds which occur at constant pulse repetition frequency, or to flatten the line spectrum of the transmitted signal that exists given a constant pulse repetition frequency, e.g., for improved interference suppression, pulse pause intervals of variable length (variable interpulse period VIP) are also used.

Coherent mixing:

To attenuate the received signal to the baseband range, it is customary for the receiver to mix the received signal with a copy of the transmitted signal. Given a spatial proximity of the transmitter and receiver, the copy can be possibly derived from the same oscillator as the transmitted signal or from a second oscillator of the receiver's own. Depending on whether a stochastic relationship exists from pulse to pulse, among the phases of the received signal and its copy, one speaks of

incoherent or coherent mixing. The coherent mixing affords a precise Doppler or velocity determination. However, to achieve the desired coherence, ~~for the most part,~~ considerable outlay must be expended to synchronize the phases (~~use, for example,~~  
5 e.g., use of lock-pulse methods or digital detectors of the transmission phase). Incoherent methods are usually called for when no velocity measurement or only an imprecise velocity measurement is required.

Monostatic, bistatic:

10 If the transmitting and receiving antennas are "distinctly" spatially distant from one another, and if the transmitted signal and its copy are derived from different oscillators for mixing purposes, one usually speaks of bistatic radar systems, in contrast to monostatic radar systems.

15 Pulse compressions:

For a pulsed radar to achieve a minimal coverage range, a minimum of total energy is required which must be reflected off of an object and integrated by the receiver. Given a predefined pulse repetition frequency, limited peak power  
20 output of the transmitter, and limited permissible integration time, the energy can only be still increased by prolonging the pulse duration. On the other hand, the correlation duration (width of the autocorrelation function) of a pulse determines the attainable resolution of a pulsed radar. By using internal  
25 pulse modulation/coding, also referred to as pulse compression methods, the correlation duration (the resolution) and pulse duration (energy and average power output and, thus, instrumented coverage range) can be theoretically defined independently of one another. Customary compression methods  
30 are linear or non-linear frequency modulation, as well as biphasic or multiphasic modulation.

~~From the technical literature, it~~ It is known that ~~the most~~  
widely varying combinations and hybrid forms of the above  
mentioned methods are used.

Fields of application of pulsed radars:

5 Monostatic pulsed radars:

In ~~the military sector~~ applications and in civilian air-  
traffic control, ~~in particular e.g.,~~ monostatic pulsed radars  
having substantial transmitting power and antenna directivity  
(beam focusing) are often used for measuring great distances  
10 and, to some extent, high velocities. Frequently, a range and  
azimuth scan is carried out, as well as a relatively complex  
Doppler processing (MTI (moving target indication), MTD  
(moving target detection) process), as well as, typically,  
pulse coding/pulse compression, e.g., chirp (dynamic  
15 wavelength change) and modulation of the pulse repetition  
frequency (VIP (variable interpulse period), staggered PRF  
(pulse repetition frequency)).

Bistatic pulsed radars:

Bistatic pulsed radars are found, ~~virtually without exception,~~  
20 in ~~the military sector~~ applications, in astronomy and in  
meteorology, where the object distances are large and are  
accompanied by great transmitter and receiver distances  
(~~baselines~~, for example, baselines in the range of hundreds of  
kilometers). High demands are typically placed on the  
25 components of such bistatic radars, particularly due to the  
requisite time synchronization of the sensors (pulse  
synchronization for distance measurement, phase  
synchronization for velocity measurement (Doppler)) over large  
spatial distances. Also regarded as difficult are the required

synchronized alignment of the viewing directions and, in some instances, allowance for platform movements.

Low-cost pulsed radars:

5 Microwave pulsed radars are increasingly being used in applications where objects are detected at small distances, using low transmitting power and a wide visual range, and where, additionally, low costs are required, such as for door openers, room surveillance, detection of motor-vehicle  
10 ~~surrounds~~ surrounding fields. Often used in this context are monostatic LPRF (low pulse repetition frequency) methods, incoherent mixing, no pulse compression, or possibly pulse compression including biphase modulation. In contrast to military radar systems or air-traffic control radars, for the low-cost pulsed radars, high-quality components are rarely  
15 used. Rather, oscillators having low frequency stability, mixers and LNAs (low-noise amplifiers) having low bandwidth and high noise factor are used, for example.

#### ~~Summary of the Invention~~ SUMMARY

20 The ~~measures according to the~~ present invention ~~render~~ renders possible a cross-echo detection and distance measurement when working with bistatic pulsed radars, ~~thus i.e., with~~ spatially separate transmitting and receiving antennas and carrier frequency oscillators, it being possible for both carrier frequency oscillators of any one transmitter/receiver pair, in  
25 contrast to ~~customary~~ conventional bistatic systems, to be run in asynchronous operation, i.e., they do not necessarily have to be frequency-synchronized or phase-synchronized ~~using~~  
~~costly measures.~~

30 The device according to the present invention is distinguished from customary bistatic radar applications, in particular by a

time-synchronized pulse modulation when working with transmitting and receiving sensors.

The present invention may be advantageously applied in connection with a pulse repetition frequency that is selected in accordance with the low pulse repetition frequency method, in particular a pulse repetition frequency that is selected to be only slowly changeable over time or piecewise constant over time.

It is thus possible to implement a bistatic pulsed radar in the low cost range as well, using low transmitting power to measure small cross-echo distances (given small baselines), and components that are not of high quality. In pulsed-radar arrays, it may be used to simultaneously measure direct and cross-echo distances. The additional cross-echo distances increase the spatial sampling of the sensor ~~surround~~ surroundings, may be used for classifying object contours, and enhance the redundancy of the sensor information.

The time-synchronous pulse modulation of the carriers of adjacent sensors and mixing of transmitted and received signals result in "image signals" having frequency components below half of the pulse repetition frequency PRF. These are referred to in the following as "cross-echo Dopplers". The mid-frequency of such a cross-echo Doppler may be adjusted via the pulse repetition frequency PRF. The power of the cross-echo Doppler supplies a continuous low-frequency signal, thereby rendering possible cross-echo detection and distance measuring.

In addition to the described implementation, a pulse compression may be carried out. A pulse jitter is likewise possible, provided that it is produced in such a way that it is synchronous for both sensors, and that the cross-echo

Doppler is still sufficiently band-limited with respect to the downstream analyzing unit.

~~Brief Description of the Drawing~~

~~Exemplary embodiments of the present invention are explained with reference to the drawing, whose figures show:~~

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a time-synchronously controlled pulsed-radar ~~transmitter-receiver pair;~~ transmitter/receiver pair.

10 Figure 2 shows a power density spectrum of the mixed, non-pulsed carriers of adjacent sensors[[;]].

Figure 3 shows a power density spectrum of the mixed, pulsed carriers of adjacent sensors, given a negligible pulse duration[[;]].

15 Figure 4 shows the power density spectrum of the mixed, pulsed carriers of adjacent sensors, given a not insignificant pulse duration[[;]].

Figure 5 shows the power density spectrum of a real I(Q) (in-phase and quadrature) signal during cross-echo reception[[;]].

20 Figure 6 shows a cross-echo Doppler control and analysis in one ~~variant of an~~ embodiment of the present invention entailing little cost outlay[[;]].

25 Figure 7 shows a cross-echo Doppler control and analysis in one ~~variant of an~~ embodiment of the present invention entailing medium cost outlay (spectrum analyzer principle) [[;]].



Figure 8 shows a cross-echo Doppler control and analysis in one ~~variant of an~~ embodiment of the present invention entailing substantial cost outlay (MTD (moving target detection) principle) ~~[[;]]~~.

5 Figure 9 shows two transmitting and receiving sensors, including representation of the direct echoes and Doppler cross-echoes, as well as of the cross-echo range scan.

#### ~~Detailed Description~~ DETAILED DESCRIPTION

10 Figure 1 shows ~~views of two simple, customary~~ pulsed-radar sensors 11, 12, of which top sensor 11 functions as transmitter (Tx), bottom sensor 12 functions as receiver (Rx). Using their respective carrier-frequency oscillators 21, 22, the sensors generate carrier signals  $x_1$  and  $x_2$  having individual carrier frequencies  $f_{L01}$  and  $f_{L02}$ . These carrier  
15 signals are ~~preferably~~ modulated by the same pulsed source 3 using the 0-1 pulse sequence  $p$ , i.e., via modulators 51, 52, pulses are impressed on the output signals of the carrier-frequency oscillators. ~~Of course, a~~ A separate pulsed signal source 3 may also be assigned to each of sensors 11, 12.  
20 However, this requires synchronizing these pulsed signal sources among one another. This may be accomplished either by using a connecting lead, or otherwise by recovering the transmitter pulse repetition frequency from the received signal and compensating for the phase offset. The phase offset  
25 may be determined by utilizing redundancy, since, due to the reversibility of signal paths ( $S11 \sim S12$ ), two cross-echo measurements of an object are normally available, as are possibly existing self-generated-echo measurements of an object. ~~(for~~ For example, assuming:  $\Delta$ =phase lead angle from pulsed signal source 1 to pulsed signal source 2;  $\text{tofK}[[;]] \equiv$   
30 cross-echo propagation time from  $S11$  to object  $K$  to  $S12$  or

return direction[:,:]  $\equiv$  cross-echo measurement from S11 to S12 relative to pulsed signal source 2; tofK21[:,:]  $\equiv$  cross-echo measurement from S12 to S11 pulsed signal source 1; it then holds that[:,:]  $\text{tofK} = \text{tofK} - \Delta$  and  $\text{tofK} = \text{tofK21} + \Delta \rightarrow \Delta = (\text{tofK12} - \text{tofK21})/2 \rightarrow \text{tofK} = (\text{tofK12} + \text{tofK21})/2$ . The signal radiated by the transmitter, once reflected off of an object and subsequently to propagation time (time-of-flight tof), is received by the receiver. Using a delay circuit/delay line 6, the receiver delays pulse sequence p by delay time  $\tau$ . If adjusted delay  $\tau$  corresponds to propagation time tof, then in the case that  $\tau = \text{tof}$ , signal  $m = p \cdot x_1 \cdot x_2$  results at the output of mixer 7, to which, depending on the time-synchronous pulse modulation, a transmitted signal, on the one hand, and, a received signal, on the other hand, may be supplied.

This (ideal) mixed signal is itself low-pass filtered, for example, in an analyzing unit 4 ~~of having a~~ downstream real amplifier 8 and ~~of real~~ mixer 7 itself. The I-signal is then available at the output of the amplifier or of the impedance converter and, in the case of a second mixer which works with the 90° phase-offset carrier, also a Q-signal, for further low-frequency signal processing. The following describes the spectrum that results for the I(Q)-signal.

1. The mixture (multiplication) of the non-pulsed carriers, ~~see e.g.,~~  $x_1$  and  $x_2$  in Figure 1, of two adjacent sensors having average differential frequency  $df = f_{L01} - f_{L02}$ , would produce a spectrum having band-limited components of around  $df = f_{L01} - f_{L02}$  and  $f_{L01} + f_{L02}$  (Figure 2). The summed component may be disregarded ~~in the following~~ due to the low-pass characteristics of mixer 7 and amplifier 8. The width of the remaining spectral component around  $df$  is determined by the short-term frequency stability of the carrier-frequency oscillators during the pulse integration time. It is important that such a band-

limited spectrum also be produced when working with oscillators that are not frequency- or phase-synchronized.

2. The pulse modulation of product  $x_1 \cdot x_2$ , which ultimately leads to ideal mixed signal  $m$ , corresponds to a sampling, the sampling frequency being given by adjusted pulse repetition frequency PRF of the pulse generator. However, in the spectrum, an ideal sampling ( $\delta$  sampling) leads to a periodic continuation of the spectrum of the sampled signal. Thus, the spectrum distributed around  $df$  is mirrored twice into each of frequency intervals  $[z \cdot \text{PRF}, (z+1) \cdot \text{PRF}]$ ,  $z$  being an integral number (Figure 3). It should be noted that a band-limited signal is always formed in the frequency range  $[0, \text{PRF}/2]$ , thus even given differential frequency  $df$ , which is substantially greater than pulse repetition frequency PRF (thus given subsampling). In this context, mid-frequency  $fa$  of the "image signal" in  $[0, \text{PRF}/2]$  and differential frequency  $df$  are interrelated, as expressed by the equation

$$df = n \cdot \text{PRF} \pm fa \quad (1)$$

$n$  being  $\in \mathbb{N}_0$  (an integral submultiple between  $df$  and PRF). An ideal sampling is ~~more or less~~ provided when the pulse duration is very short as compared to the shortest period duration of the sampled signal, i.e.,  $T_p \ll 1/df$ . If this is not the case, the amplitudes of the repeated spectral components fall off in accordance with an envelope defined by the pulse shape and the not insignificant pulse duration (Figure 4). In the case of a square-wave pulse of length  $T_p$ , the envelope is, for example, a  $\sin x/x$  characteristic having the first zero position at  $1/T_p$ .

3. The spectrum of the real IQ-signal falls off markedly above the limiting frequencies of the mixer and amplifier/impedance converter, which are typically substantially lower than

differential frequency  $df$  and generally resemble a characteristic shown in Figure 5. This limited signal component, formed by a cross echo in the I(Q)-signal and having its essential frequency components below  $PRF/2$ , is referred to in the following discussion as cross-echo Doppler. A direct echo of an extremely rapidly moving object having corresponding Doppler frequencies around  $f_0=df$  would lead to a similar signal.

4. It should be noted that image frequency  $f_a$  of the cross-echo Doppler having predefinable pulse repetition frequency  $PRF$  (given a slowly changeable time frequency  $df$ ) in accordance with the above equation (1) may ~~always~~ be adjusted to a desired value. In particular, by selectively setting the pulse repetition frequency, it is possible to ensure, on the one hand, that image frequency  $f_a$  is always below the limiting frequency of the mixer and amplifier. On the other hand, given parallel reception of direct echoes of the sensor, it is possible to ensure that image frequency  $f_a$  is always above maximum Doppler frequency  $f_{Dmax}$ . This may be understood as a "frequency-multiplexing" use of the I(Q)-signal, where the direct echoes and cross echoes are in separate frequency ranges.

An important condition for a distinct separation is, ~~of course,~~ that the local mixing oscillators be short-term frequency-stable to such an extent that the bandwidth of  $x_1 \cdot x_2$  is always smaller than  $PRF/2 - f_{Dmax}$ .

5. Submultiple  $n$  and image frequency  $f_a$  characterize the momentary differential frequency of a sensor pair for which cross-echo reception exists. Thus, when working with sensor arrays having more than two sensors, where the differential frequencies of all relevant sensor pairs deviate significantly from one another, a transmitter identification is also

possible given a parallel reception of a plurality of cross echoes.

The device according to the present invention ~~is characterized, in particular, by~~ provides, for example, the following features:

- synchronous pulsed driving (connecting lead, or by recovering the transmitter pulse repetition frequency from the received signal and compensating for the phase offset);
- using the cross-echo Doppler in I, Q-signals or in signals derived therefrom, below PRF/2;
- control/regulation of mid-frequency  $f_a$  of the cross-echo Doppler by changing the pulse repetition frequency.

From ~~this refinement~~ the above-described features, one derives the following advantages/~~possibilities~~ are provided, for example:

- power measurement (or the like, e.g., amplitude, quasi peak, etc.) of the cross-echo Doppler supplies a continuous low-frequency signal for cross-echo detection and cross-echo distance measuring;
- for digital ~~further~~ processing, cost-effective sampling of the low-frequency power signal possible, using low sampling rates (determined by object-sensor dynamics and scan rate);
- cross echoes may be analyzed in parallel to direct echoes, since the cross-echo Doppler in the I, Q-signal is placed with the pulse repetition frequency in a separate frequency range (frequency-multiplexing operation);

- a costly phase synchronization of the carriers is not necessary, but a minimum short-term frequency stability (during the pulse integration time) of the possibly free-running oscillators is required;

5 - no high demands on the bandwidth of the mixers and low-frequency amplifiers (above selectable image frequency  $f_a$ );

- the mid-frequency of the cross-echo Doppler may be kept constant via the pulse repetition frequency, e.g., in the case of a drifting carrier-frequency differential (response to  
10 temperature changes, etc.);

- active suppression of otherwise sporadically occurring crosstalk, which occurs in sensor arrays in response to unsynchronized operation using a fixed pulse repetition frequency when the cross-echo Doppler, e.g., due to  
15 temperature drift of the carrier frequencies, happens to fall within the frequency range of the direct echoes ( $0 \dots f_D$ );

- indirect monitoring of the carrier frequencies as diagnostic function (built-in test);

- in sensor arrays, a cross-echo transmitter identification is  
20 possible by estimating the carrier-frequency differential on the basis of identified cross-echo Doppler mid-frequency  $f_a$ , the pulse repetition frequency, and integral submultiple  $n$  of the quotient of  $df$  and PRF;

- ~~in addition,~~ customary pulse-compression methods may be  
25 used; and

- cost-effective hardware implementation is possible, e.g., variant of an embodiment entailing little outlay in accordance

with Figure 6[[:]], i.e., controllable PRF generator having PLL/DDS, analog bandpass BP and power measurement/half-wave (one-way)rectifier.

5 The An example embodiment of the device according to the present invention ~~entails~~ has the following ~~outlay~~ requirements:

- synchronous pulsed driving is necessary[[;]] (connecting lead, or by recovering the transmitter pulse repetition frequency from the received signal and compensating for the phase offset using redundant measurements);

- for the fa control, the pulse repetition frequency must be modifiable in small steps. Thus, the steps must be all the smaller, the greater the ratio  $df/PRF$  is, and the smaller the bandwidth of a bandpass is selected;

- in the sensor arrays, for each adjacent sensor and  $I(Q)$ -signal, the power of the cross-echo Doppler must be determined.

15 Different ~~variants of~~ embodiments of the present invention are described in the following sections.

20 It is assumed that all example variants of the present invention use customary pulse-radar heads in accordance with Figure 1, i.e., each transmitter includes at least one carrier-frequency oscillator and modulator (or fast-action switch) for pulse modulation; each receiver includes at least one pulse-delay unit, one carrier-frequency oscillator, one modulator (or fast-action switch) for pulse modulation, and one mixer for attenuating the received signal (Figure 1). In a sensor array, each sensor may be composed of a transmitter and

receiver having only one carrier-frequency oscillator, which feeds the transmitter and receiver in parallel.

Thus, the ~~proposed~~ device according to the present invention does not require any modification of customary radar heads, as used for monostatic operation, as well. All ~~variants of~~ embodiments of the present invention have in common a pulse-synchronous driving of all sensors, i.e., of all transmitters and receivers, and a frequency-selective analysis of the I-signals and optionally of the Q-signals. The ~~variants~~ embodiments only exhibit differences in the signal processing of the I(Q)-signals.

~~Variant~~ Embodiment entailing little outlay (Figure 6):

I- and optionally Q-signals are filtered by analog bandpass filters 31 using constant resonant frequency  $f_{res}$ . In this context, using the pulse repetition frequency, an analog or digital control 32 of mid-frequency  $f_a$  of the cross-echo Doppler ensures that, in the case of cross-echo reception, maximum power output is always available in the pass range of the bandpass filters. Power estimation  $y$  of the cross-echo Doppler is carried out by analog analysis of the bandpass output signal, e.g., simple rectification (half-wave rectifier/square-law detector) and smoothing. For digital further processing (detection, distance determination, e.g., by scan operation, see detector outputs  $c_I(\tau)$ ,  $c_Q(\tau)$ ), a sampling 33 of signal ( $y$ ) at a low rate is possible.

~~Variant~~ Embodiment entailing medium outlay (Figure 7):

Spectrum analyzer principle: I- and optionally Q-signals are mixed (multiplied) with sinusoidal signals by oscillators 42 tuned to a monitoring frequency  $f_{mon}$ , e.g., direct digital synthesizer DDS. If mid-frequency  $f_a$  of the cross-echo Doppler



is close to  $f_{\text{mon}}$ , a low-pass signal is formed, whose power output, subsequent to low-pass filtering 41, may be estimated analogly or digitally, and analyzed as in the variant entailing little outlay. The advantage of this ~~variant~~  
5 embodiment is that mid-frequency  $f_a$  does not need to be kept constant, rather that  $f_{\text{mon}}$  may follow  $f_a$ . In addition, the entire spectrum from 0... PRF/2 may be monitored for external interference. Moreover, a sampling of a low-pass signal at a low rate is already possible, and thus a narrow digital low-  
10 pass filtering and very precise determination of power output.

~~Variant~~ Embodiment entailing greater outlay (Figure 8):

I- and optionally Q-signals are sampled 61 pulse-synchronously, i.e., at a rate that is equal to the momentary pulse repetition frequency. A digital filtering by a bandpass  
15 filter bank then follows, compare Doppler filter banks typical of MTP radars 62, and a digital power output estimation. This corresponds to an estimation of the I-, Q-power density spectrum in sub-ranges or to the entire spectrum, from 0... PRF/2. To this end, a numerically efficient FFT (fast Fourier  
20 transform) may also be used. The advantage of this ~~variant~~ embodiment is that the power output and mid-frequency of a cross-echo Doppler may be determined very reliably from the spectrum, even when, initially, there may be no past information available on the mid-frequency (capture or scan  
25 mode). There is maximum flexibility with regard to the (digital)  $f_a$  specification/control. In addition, a reliable detection of interference signals is possible. In sensor arrays, the cross-echo Dopplers of all adjacent sensors may be monitored simultaneously.

30 Figure 9 illustrates two spaced-apart radar sensors 71 and 72, which are each equipped for transmitting and receiving operation. The direct echoes are denoted by 711 and 721. They

are reflected off of wall 8. Object 9 in the nearfield of the radar sensors cannot be detected by these direct echoes. Detection may only be carried out via cross echo 92. Cross echo 91 is reflected off of wall 8. In the cross-echo range scan likewise depicted in Figure 9, cross-echo Doppler 92 first appears, conditionally upon the shorter propagation time. Cross-echo Doppler 91 appears with a delay that is dependent on the propagation time. The analysis of the cross-echo Doppler enhances the spatial sampling in the short range (angular resolution), permits the classification of object contours, and increases redundancy, particularly in the distant range, ~~i.e.~~ Hence, on the basis of the two measured values of direct echoes 711 and 721 and of cross echo 91, it is possible to verify that object 8 is actually one contiguous reflection surface. If direct echoes 711 and 721 were to arrive, but not cross echo 91, then it could be a matter of two different objects in the distant range. It should be noted, however, that given a larger object 9, cross echo 91 could be blocked by wall 8. To increase the reliability of redundancy and detection, a cross-echo analysis of more than two radar sensors ~~among themselves is advantageous~~ (sensor array) is advantageous.

Abstract

ABSTRACT

In a device for bistatic radar applications, ~~in particular,~~ at least two spaced-apart radar sensors ~~(11, 12) are provided,~~ having separate carrier-frequency oscillators ~~(21, 22) are~~ provided, which do not require phase synchronization. The pulse modulation is carried out time-synchronously for all transmitter and receiver pairs. The cross-echo signals can be analyzed in an analyzing unit ~~(4)~~, in which a mixing ~~(7)~~ of the transmitted and received signals takes place.

10 ~~(Figure 1)~~